ATOLL RESEARCH BULLETIN

No. 1

Basic information papers on coral atoll ecology

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These papers were prepared at the request of the Pacific Science Board as background information for use in two symposia on coral atoll research held in Washington, D. C., January 12, 1951, and Honolulu, T. H., February 5 and 6, 1951. The purpose of the symposia was to plan a program of scientific research pertaining to the general ecology of coral atolls.

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National Research Council
Washington 25, D. C.

Coral Atoll Symposia
12 January 1951, Washington
5 and 6 February 1951, Honolulu

INTRODUCTION

The Coral Atoll Project of the Pacific Science Board of the National Research Council is associated with Research Project E.6 (copy attached) of the South Pacific Commission which is concerned with Economic Development of Coral Islands. The phase of this project undertaken by the Board is largely in the field of basic research and involves essentially an ecological approach to the study of environmental factors effecting life on coral atolls. This involves three activities:

A. Field work conducted according to a uniform plan by teams of selected scientists on sample atolls in different climatic and cultural areas of the Pacific;

B. The assembling and correlation of known information particularly from literature on the Environment and Economics of Inhabitants of Coral Atolls; and

C. Program planning, advice, and evaluation of the results of research being conducted under A and B by an advisory committee of scientific specialists in fields represented in the Atoll Research Program.

During 1950 and early 1951, with Department of Navy assistance and the help of a grant of funds from the Office of Naval Research (under A), field studies on Arno Atoll in the Marshalls were conducted by thirteen specialists) in the fields of Anthropology (two), Geology (two), Geography (one), Marine Ecology (two), Botany (one), Vertebrate Ecology (one), Invertebrate Ecology (two), Soils and Crops (one), and Hydrology (one). Their team report and their final technical reports are now in preparation. Under B, a systematic combing of the extensive literature on coral atolls was begun in both Honolulu and Washington, and an annotated bibliography compiled. Under C, meetings of an ad hoc advisory group have been called in Washington (January 12), and in Honolulu (February 5 and 6).

The development of plans for the 1951-52 phase of the Coral Atoll Project will depend on the evaluation and recommendations of the ad hoc advisory group. It is hopefully anticipated that the Office of Naval Research will continue their support of this long range project involving basic research with applied aspects. Coral islands, wherever found, are of concern to the United States Navy.

H. J. Coolidge

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SOUTH PACIFIC COMMISSION

RESEARCH COUNCIL

Project No. E.6.

ECONOMIC DEVELOPMENT OF CORAL ISLANDS.

The general thinking on problems in the Area of the South Pacific Commission has been devoted largely to agriculture and improvement on volcanic and other large land-mass islands. The great per cent of the indigenous population is found on the large islands. But there is no place where the problems are so acute and their solution of greater concern to the peoples involved than on the coral or low islands. Moreover, the large islands, administered by diverse staffs, in which that for agriculture is always-prominent, are able to cope with their own problems to a great degree. The low islands are usually destitute of experimental resource, trained and experienced technical personnel. They may receive the benefit of sporadic investigation, but seldom of sustained studies based on and devoted to coral island production problems.

The economic circumstances on the coral islands are restricted. There are no pastures; there are no cattle. A few pigs and chickens constitute the livestock. Coconut palms cover most of the islands, with a few other tree species for local needs only. Often the population carrying capacity of the island or atoll has been reached. Copra has been the principal money crop. The atoll sun-dried copra, though small in total tonnage, is regarded as the best obtainable. Pandanus mats have been a second source of profit, but in this much depends on the local supply of fibre, skill and artistic imagination.

At this time there is no substitute for copra. The meagre, mineral-deficient soils do not support palms in full health and vigor. There is in sight no plant which offers itself as a substitute for the cocos, no product which can now replace copra for income. Coconut palms are replaced from time to time, and many are now at the end of their useful life. Replacements should be studied to the end that improvement in yield and vigor may be secured.

Food plants consist of breadfruit, pandanus, taros, bananas, some Polynesian chestnut, some citrus, arrow-root as a reserve generally, and scattered, individual plantings, as pineapples and sweet potatoes.

Pigs and poultry are kept in small numbers, the population of each being limited by the available feed.

The lagoon and reefs may supply fish and crustaceans. Pearl and trochus shells have a market, but it is not always profitable.

The low island people of the SPC area are the most deserving of assistance in the field of horticultural and economic security which the Research Council can promote. No programme of improvement will be rapid, because they cannot sacrifice present production for new or changing agriculture on a large scale.

Recommendations.

It is recommended that:-

1. A consistent program of coconut palm improvement be prepared, designed to:-

   (a) improve health and vigor;
   (b) increase yields; and
   (c) increase resistance to pests and diseases.

2. Food plant program be undertaken to study:-

   (a) the physiology of the breadfruit tree;
   (b) the preparation and extension of pits for growing wet land taro;
   (c) the introduction of bananas suitable to the area;
   (d) ways and means to increase the production of other food plants, especially those requiring additional fertiligy, as sweet potato, vegetables, citrus;
   (e) the supplementary nutrition of swine, ration of iron salts, and vaccination; and
   (f) improvement of poultry, both in egg laying capacity, time and weight development of birds, and freedom from diseases.

3. Information be gathered applicable to the extension of their commercial well-being, with attention to the increase in shell fisheries, either by planting of trochus and pearl shell, and the possibility of silk-grade sponges as a long time project.

4. Until such time as the economic situation on the low islands can be studied and their needs more particularly resolved, no large research allotment is requested.

5. In view of the urgent necessity to implement project E.5, the Administration of the Gilbert and Ellice Islands Colony be asked to proceed with the plan to establish a small agricultural station at ABEMAMA where there are facilities and where typical conditions are available.

6. In order that the work may proceed at an early date, an annual grant for 3 years of £ 500 be made toward the cost of wages, materials, maintenance and recording, on condition that the South Pacific Commission be kept informed of progress and results, and that the work is carried out to the satisfaction of the Commission.

7. That all administrations in whose regions atolls occur be asked for information in terms of recommendations (2) and (3).

8. That publication in Fiji Agricultural Journal of available information on these subjects be proceeded with for the guidance of resident officers.

9. That the Pacific Science Board of the National Research Council be invited to sponsor and finance an economic survey with special attention to the by-products of the islands. It is considered that this can be completed in 6 months.

Budget Note:

The Total provision recommended is £ 1500, of which £ 500 is required in 1950; £ 500 in 1951, £ 500 in 1952.

I. ECOLOGICAL RESEARCH ON CORAL ATOLLS

Coral atolls, scattered over a large part of the tropical seas of the world, provide a natural laboratory for research in tropical ecology that is unique and has scarcely been utilized. Although a certain amount of marine research has centered around atolls, their biota is so simple that it has not attracted much attention from students of land ecology. However, this very simplicity provides a situation almost ideal for studies of total environment and of human adaptations to and effects upon an environment.

Ecological research may take many forms. Essentially, ecology is a point of view from which almost any subject matter may be considered, that which emphasizes the interrelationships of living things and their environments. One of the most interesting types of such research is the study of a situation to determine what organisms inhabit it, what effects the various characteristics of the situation have upon them, what effects they have on the physical surroundings, and, finally, what effects they have upon each other. This applies not only to individuals of different kinds, but also to the members of one population of the same kind. The most severe competition of all is that between members of the same population. Further, it must not be overlooked that man is, of all the kinds of organisms in almost any situation, the one that exerts the strongest and most general influence.

Situations are usually selected for study because they are representative of a class of similar ones, so that the results of the research may be applied to the others of the class and may be compared with results of similar studies of other representatives to arrive at generalities. As in many other fields, the ecologist studying situations is able to adopt either of two very different approaches, that of studying one or a few examples very intensively, or that of studying many examples but much less thoroughly. Which of these approaches is best is a philosophical question that is not likely to be solved very soon. It seems unquestionable, however, that where both methods may be applied to one problem, the results will be more sound than those from either one or the other.

The complexities dealt with by ecology are probably greater than those facing any other science. Involved are, necessarily, a complete knowledge of the physical situation and the organisms in it, and their characteristics, requirements, and behavior. This is merely basic information. Then the innumerable processes taking place must be detected and understood. Finally, the effects of these processes on each other and on the various organisms must be determined, and an understanding of the resultant of all of these processes and effects arrived at, which should be an understanding of the situation itself. This ideal final product, this understanding of total environment, is the ultimate objective of ecological research.

Its value is so apparent that it scarcely needs to be pointed out. Such understanding furnishes the only real basis for complete control over a situation, the only basis for predicting the consequences of any use or alteration of any

factor in an environment, and the only possible basis for any rational sustained program for permanent habitation of any area by man or his dependent organisms. In other words, it is the only completely sound foundation for conservation and management of any segment of the total resources of the world we live in.

Most ecology gives the impression of being mired down in such a mass of complexity as to be getting nowhere, or of dwelling on single items out of context of the web of which they are a part. This is a logical result of the enormous complexity of almost all situations, and is likely to be extremely discouraging to one who has vision enough to see the whole picture.

The logical way out seems to be to begin with some of the simpler classes of situations. An understanding of some of these may well provide the methods and basis for approaching more complex ones. And, indeed, such an approach seems to have given the best results so far. The ecology of the far north, of deserts, of ponds and lakes, of certain grasslands, and of moorlands have made the most substantial progress.

Coral atolls provide another class of such simple situations, and one of the few possible ones in the tropics.

One of the reasons why a study of total environment is one of the most refractory and difficult of all lines of investigation is that it does not lend itself readily to an experimental approach, as the very process of experimentation will certainly modify the environment being studied. Ordinary experimental technique consists of keeping certain variables constant and manipulating others, in order to ascertain their effects. The nearest thing to a possibility of such an approach in studies of total environment is in a type of natural situation where certain factors are reasonably constant while others differ in various examples.

Coral atolls present nearly an ideal set of such situations. They are flat, eliminating all of the variables commonly associated with altitudinal differences. They are tropical and oceanic, eliminating significant temperature differences. They are calcareous, eliminating most significant substratum differences. They are structurally simple, minimizing hydrologic complexities. Their flora and fauna are small, reducing biological influences and making the biotic communities relatively simple. Thus a fairly understandable basic ecological pattern is discernible. Over this are laid variations in precipitation, size of island, distance from geographic sources of fauna and flora, period of human occupancy, cultural character of human occupancy, etc.

Understanding of the effects of these variable factors and of the functional dependencies between them and other factors may be approached by making comparative studies of several different atolls exemplifying differences in such variables as mentioned above. Comprehensive studies, such as those made on Arno by a team of workers, would be highly significant if available in addition for, say, a small dry atoll in the central Pacific, a small moist atoll in the central Pacific, a moderate sized moist atoll remote from large land areas, such as in the Tuamotus, an uninhabited moist atoll, possibly Maria in the Australs, and an atoll near large land areas, such as one in the Melanesian area, i.e., Sikiana.

If, over a period of several years, such a series of detailed, integrated investigations might be made, a fairly broad base of modern reliable comparative information would be established. Into this would be integrated the enormous amount of existing information being brought together by the bibliographic phase of the investigation. As a result it might be possible that a coherent and understandable picture of a limited tropical total environment would emerge, comparable to that developed for English mountains and moorlands by Pearsall (1949).

The significance of this in terms of human values is quite clear. There is no question that, in spite of the limitations of this atoll type of environment, human populations are going to live there, just as they have for many hundreds of years, at least. Atoll peoples had, left to themselves, evolved a mode of life very well fitted to this environment, and in a fair equilibrium with it. Though rigorous and simple, it was, so far as we may know, a happy and satisfactory existence. These peoples had come to terms with their environment and made the necessary adaptations for life in it.

During the past century and a half, expanding Western European Civilization has burst in upon these self-contained microcosms, inevitably shattering the equilibria established over the previous centuries. Disease, an altered religion, commerce, war, and confusion were the gifts of this alien culture. To some this change may be a matter of regret, to others merely a matter of intellectual interest, to still others it is moral elevation, while some call it "progress". At any evaluation, it must be accepted as a fact, and as irreversible. Modern transportation has become so effective that isolation, even for these remote atolls, no longer exists. The influence of western culture must now be reckoned with as a factor in any new equilibrium that is brought into being. Life for these people is thereby enormously complicated.

If modern science is to be of any real benefit to these peoples, as well as to others, it is probable that it must be in helping them to come to terms again with their environment, the new environment that has resulted from the shattering of the old. It is here that ecology, particularly the aspect of it dealing with understanding of total environment, is of vast importance. Understanding is certainly the first requisite toward dealing with anything. If this study of atolls contributes, over the years, to the readaptation of atoll peoples to their place in the world, as well as providing a key to the understanding of other, more complex total environments, it will have amply justified itself.

F. R. Fosberg

II. GEOLOGIC STUDIES OF CORAL ATOLLS

Coral atolls are organic communities isolated from influences of continental landmasses. The organisms that build the reefs are responsive to their physical and chemical environment, and, as they build the reefs and islands, these in turn influence the physical and chemical environment so as to provide a variety of ecologic habitats. Geologic studies of reefs, islands, and lagoons should provide the biologist with a pattern of zones of growth, erosion, and sedimentation, and should indicate the relations of these zones to environmental factors. The biologist's studies of the organisms in each zone should in turn help the geologist in interpreting the geologic history and paleo-ecology of the atoll from drill cores.

At present there are fairly well-integrated studies of the physical and chemical environment, the biology, and the geology, from very few atolls. Work at Bikini and the northern Marshalls has shown some relations of the pattern of reef zones and lagoon sedimentation to the prevailing conditions of surf, tides, and currents, and to changes in temperature and chemistry of waters on the reefs. It has been shown by drilling that the rocks at Bikini down to 2556 feet include a relatively complete section of limestone, mostly unconsolidated, through the Miocene and possibly including Upper Oligocene.

The relations of reef structures to the environment found at Bikini may not hold at other latitudes or in other island groups, and further work on a number of atolls at different latitudes both north and south of the equator is necessary.

Future geologic work should include:

1. Drilling. A deep hole to the basement rock should be drilled on an atoll that has been well studied. At Bikini such a hole would probably be 4000-7000 feet deep.

Holes to depths of 2500 feet, such as the one drilled at Bikini, should be drilled on atolls in every major island group. Lines of shallower holes to 300 feet or less should be drilled across islands and reefs on both windward and leeward sides of several selected atolls to relate the subsurface rocks to the topography of the lagoon and offshore slopes.

2. Oceanographic work. The physical environment of a number of atolls must be studied. These studies should include wave and current studies over reefs, lagoon circulation and exchange with the ocean, and accurate gauging of tides.

The chemistry of sea water, especially of that over reefs, is very little known. Oxygen, salinity, and pH measurements carried out over the diurnal cycle, and under different seasonal conditions, should be made on selected atolls.

3. Adequate facilities should be provided for lagoon studies. These facilities should include large ships with both shallow and deep recording fathometers, winches for dredging, and bottom sampling and coring apparatus. Smaller craft such as landing or rearming boats should be available for near-shore studies or for shallow water diving. A trained deep-sea diver could add greatly to our knowledge of lagoons in the zone of photosynthetic action.

4. Adequate aerial photographs, preferably overlapping photos on a scale not less than 1:5,000, should be obtained of as many atolls as possible.

The problem of the origin of islands on reefs might well be attacked by a survey of one of the islandless atolls, such as Ngulu Atoll in the western Carolines, or by a comparative study of Kayangel and the adjacent Ngaruangl atolls north of Palau.

Whether an island can form and become stabilized by vegetation under present conditions might be determined by finding out how large a sand and gravel accumulation, such as a bar or "temporary" island, must be before it can hold a freshwater lens sufficient to permit the growth of vegetation.

J. I. Tracey, Jr.

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III. PACIFIC METEOROLOGIC PROBLEMS

The science of meteorology stands at a point where additional insight into the mechanisms and characteristics of the general circulation or hemispheric-flow patterns has become a problem of foremost interest. To have attained this point, it must be recognized that climatologic data and climatic research have been important stepping stones. It happens, however, that there are still great areas of the earth's surface for which inadequate, and in places, negligible climatologic data are available. In fact, there are areas where generalized upper air patterns are perhaps better known through the process of interpolation than detailed surface climatology. This is perhaps the case over broad ocean areas of the central and western Pacific.

Research in that part of the Pacific characterized by atoll development provides an opportunity for the collection of meteorologic data not only valuable to a knowledge of local biology and physical geography but also to broad problems of meteorology and climatology.

Intensive research in Pacific meteorology would demand resources far more widespread than those contemplated for any atoll research project. It is the purpose of this brief statement only to point out that date of regional as well as local significance can be obtained with the left hand, as it were, of any scientific project in the Pacific area. A very few of the possible problems are listed on which specific data might be readily obtained in connection with other work:

1) Estimates of the mean annual rainfall over the open ocean are, for large areas, very crude. Small islands of little relief offer opportunity for obtaining rainfall data which approximate the fall over the open sea.

2) Data on rainfall amounts in conjunction with indications of time of beginning and ending of rain, and concurrent observations of the time of day of specific shifts of wind direction, provide data for the analysis of the effect of the land mass on sea-land breezes. A problem of some interest is the minimum size of island required to cause sea-land breeze effects.

3) One of the important low-latitude meteorologic problems of the upper air is the nature and distribution of pressure waves in easterly wind currents. Though radiosonde data are required for detailed analysis, daily or twice daily observation of the direction of movement of clouds, particularly middle and high clouds, can be useful.

4) Temperature records are less significant meteorologically, from small island masses, than some other types of record. In oceanic areas, air temperature very near the beach can be compared with water surface temperature with profit. Temperature data requirements, however, should probably be dictated by biologic rather than meteorologic research needs.

Luna B. Leopold

IV. SOILS

Our present knowledge has two aspects: soil development per se (pedology) and the soil in relation to plant growth (edaphology).

SOIL DEVELOPMENT

Present state of knowledge: Most of information on atolls is from observations by biologists, geologists, etc. There are no analytical data of consequence in the literature. The Arno work characterizes only the wet atolls.

From studies on old raised coral islands the ultimate course of soil development on such materials is known. Present atoll soils are regosols and lithosols, representing relatively primitive stages in this development. Apart from catastrophe or uplife it is probable that these soils are foredoomed to self extinction as weathering reduces land height to sea level.

The probable short time course of soil development and effects of climate on it are inferred from observation, and from studies elsewhere, rather than known with any certainty. There are differences in existing soils attributable to moisture regimes, salinity, typhoon history, guano deposits, vegetation and man's activities but knowledge of their effects is sketchy and not well organized.

Suggested future research: Land formation, composition, age and weathering; permanency in relation to typhoons and solution. Soil development in relation to climate and time.

SOIL IN RELATION TO PLANTS

Present state of knowledge: As a first approximation, some of the probable effects on native vegetation and agricultural plants can be inferred from studies elsewhere. Ecological studies have stressed effects of soil and ground water salinity on vegetation but much more detailed information is needed. There are indications that soil nitrogen and phosphorus, and hence the cycle of these elements in vegetation, may be considerably affected by soil organisms (Baas Becking's notes) and sea birds. The Arno observations indicate soils are not as "impoverished" as often believed but some mineral deficiencies are known or suspected. The physical properties of soil can only be considered adequately in relation to moisture regimes and groundwater.

Suggested future research: Many investigations of this nature are probably best undertaken in connection with other projects; thus detailed observations should be made in connection with ecological studies, and agricultural improvement will require fertility investigations. Determination of the causes and distribution of the coconut maladies observed may require long term investigation. Evaluation of the soil resources of a given area will be needed for estimates of its potential productivity and carrying capacity.

Earl L. Stone, Jr.

V. FLORA AND VEGETATION OF CORAL ATOLLS

The flora of atolls is best discussed under several major headings. These are 1) Vascular plants, 2) Bryophyta, 3) Fungi, 4) Soil flora, 5) Marine algae.

1. The vascular flora of atolls is known in a general way, but as much from inference as from actual collections and observations. It is known that it is limited in numbers and that its most striking components are from the pantropic strand flora, with some admixture of more mesophytic elements in localities where conditions permit. Of the several hundred atolls and low islands known, we may say that the floras of Bikini, Rongelap, Rongerik, Eniwetok, Arno, Kapingamarangi, Satowan, Pingelap, the Hawaiian atolls, Rose, the Pacific Equatorial Islands, and Johnston Island are fairly thoroughly known. Those of most of the other Marshall Islands, Flint, Vostok, Caroline, Tubai, Maria, certain of the Tuamotus, Funafuti, Canton, Wake, Nomwin, Ant, Mokil, Ulithi, Woleai, Nukuoro, Cocos Keeling, Maldives, Laccadives, Chagos, and Alacran Reef, are more or less known, having been collected by more than casual visitors. The remainder, possibly the majority, are either not known at all or only very casually.

Recent intensive collecting on a few atolls has dispelled the idea that atoll floras are so uniform that they are not worth bothering with. Differences have emerged which suggest that if the floras of all of them were thoroughly known very significant patterns might well emerge. Certainly understanding might develop as to the effect of distance and habitat on the effectiveness of dispersal. The idea has also been suggested that if a large number of sea level atolls and those elevated ones known were thoroughly collected, statistical treatment of the results might yield evidence on the putative recent eustatic shift in sea level.

2. Only a few scattered bryophytes are known from atolls. On some of the dryer atolls there obviously are none. But very few collectors have been on any atoll long enough to bother about hunting for mosses. It may be safely stated that the bryophyte flora of atolls is essentially unknown.

3. The fungus flora is dealt with separately in a paper added by Dr. Rogers.

4. Notwithstanding its obvious importance, the microflora of the soil is scarcely known for any atoll. The work on the collections of Dr. Taylor from Bikini and neighboring atolls is the only exception. It has shown that there are at least notable floras of Chytridiales and Actinomycetales in atoll soils. Dr. Baas Becking's investigations on the blue green algae in the soil crust suggest that here is a field of great interest awaiting investigation.

5. The marine algae are also dealt with separately in the attached paper by Dr. Taylor.

The vegetation of atolls is even less well-known than their flora. Superficially the vegetation of most of them is rather similar, which has given rise to the notion that there are no significant variations in atoll vegetation. It is, however, obvious that there is a perfectly graded series from extremely dry and barren to very wet and lush atolls. Their surface features, land areas, and history of human occupation add other very striking variations. And it is very obvious that the role of hurricanes and typhoons in determining the vegetation is an important one.

Though superficial descriptions of atoll vegetation are many, careful, detailed ones are almost lacking. Millspaugh's paper on the vegetation of Alacran Reef, the descriptive parts of the Funafuti report, Rock's paper on Palmyra, Setchell on Rose Atoll, Christophersen's papers on the Central Pacific and Hawaiian atolls, descriptions of one or two atolls in the U. S. Commercial Company reports, and Taylor's recent book on Bikini are about all that are available. Taylor's book deserves further comment. Never before has such a thorough work on either the flora or the vegetation of an atoll been written. From now on it will be a basic point of orientation and comparison for all future studies.

Obviously, with such vast gaps in our information on both floras and vegetation of so many atolls, no opportunity should be neglected for further collecting and observation. Emphasis might well be laid on longer visits than the hit-and-run type so common in the past. This is especially necessary if significant descriptions of vegetation are to be prepared. Furthermore, no adequate picture of the cryptogamic flora, especially of the parasitic forms, the minute soil inhabiting plants, and the marine algae will be obtained without specific efforts being made toward these ends.

Another obvious task that should be undertaken is the preparation of a flora of coral atolls. This should be planned to include the plants recorded from atolls in the literature, records available in herbaria, and all new information that is accumulated during the course of the investigations carried on by this project, the Bikini project, etc. It could be carried in card-catalog form for several years, then brought together for publication. At least three people should be concerned with its preparation, one for vascular plants and bryophytes, one for fungi, and one for algae. These could obtain such collaboration as would be necessary from specialists of their acquaintance. The main centers of deposit of atoll plant specimens are the Bishop Museum, Honolulu, the U. S. National Herbarium, Kew, and the Paris Natural History Museum. These would have to be visited and combed for material.

F. R. Fosberg

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V. (a) FUNGI

The fungi of the atolls have been little collected, and there are almost no published reports on them of any consequence. The German and Japanese students who gave occasional lists of fungi of the Pacific islands from the early 1800's into the 1940's seem to have devoted most of their attention to high islands. What fungi were reported from atolls seems to have been specimens picked up in passing by collectors seeking vascular plants, and they are all large fleshy or woody species. Except for the Marshall Islands, atoll fungi remain almost unknown. From that group only 16 fungi had been reported up to 1947. The recent book by Taylor, and the lists begun by Rogers, indicate that fungi are considerably more numerous in this group. Together these authors list 43 species; but since of their collections the Ascomycetes, the most abundant groups of Basidiomycetes, and the whole mass of foliicolous forms remain mostly unnamed, it is certain that in this best-studied archipelago the majority of fungi - at least three quarters of the species - remain unknown.

The gaps in present knowledge are such that no recommendation for an area of concentration is possible. Economic fungi - those causing disease of man and of higher plants, and those causing decay of timber and fabric - are almost completely unknown even from the Marshalls; distribution of species among atolls, and the relation of atoll to high-island fungi, are equally unknown.

D. P. Rogers

VI. ATOLL RESEARCH IN ZOOLOGY - LAND AND MARINE

The land species of atolls constitute a depauperate fauna of very few species dependent on the attainment of this isolated habitat after its formation as land, and upon the tolerance of such species for any habitats to be found upon atolls. The land species are mainly concerned with the forest ecology of leaf mold accumulation; such species as the minute land snails, for example. A second group is useful in the reduction or elimination of insects bothersome to man or to his efforts in agriculture. The small lizards belong to this group. The third group, some of which are scavengers of the atoll economy, may be, and are used in some cases for food by the atoll inhabitants. For example, the small rats may help support the cats, dogs, and swine of the natives. The large Coconut or Robber Crab, and birds and bird eggs are usually a direct source of food for the inhabitants.

The marine species of animals found in and around coral atolls are far less restricted than the land faunas, yet form a reduced fauna in comparison with that of continental or high-island habitats in the same geographic areas. The invertebrate animals particularly are of major importance in supporting the planktonic and benthic pyramids of food supply derived from the Ocean by the atoll inhabitants. Certain forms, such as the larger crustacea (Crabs & Spiny Lobsters), Mollusks (Clams & Oysters) are eaten directly. The many other species serve to help the growth of the vertebrate food supply that is the major direct food crop derived from the oceanic waters surrounding the atoll and filling the lagoons. Fish probably constitute the major portion of this crop on all atolls. Of secondary importance for food are the Sea Turtles, and the group of Porpoises; secondary because only captured occasionally. The birds, sometimes seasonally cropped from their rookeries, are usually Sea-birds, fed from the Ocean.

From a very hasty survey, one may say that most of our present knowledge of the Zoology of Coral Atolls is a widely scattered series of isolated faunal studies. That is, the great majority of this scanty knowledge is simply the determination of what species may be present in a particular closely circumscribed area. In the past there has been less time or inclination to study the ecology of species critically, except of course in the case of a few commercially valuable animal products, such as the Oceanic Pearl Shells.

Coral Reef and Atoll studies in Zoology include more or less complete faunal studies at: Tur (Red Sea); Mahebourg (Mauritius); Mascarene Ids; Maldive Ids; Laccadive Ids; Andaman Ids; Nicobar Ids; Cocos-Keeling and Christmas Ids; Port Galera (Philippines); Mariana Ids; Solomon Ids; Great Barrier Reef (Australia); Marshall Ids; Funafuti (Ellice Ids); Phoenix Ids; Fiji Ids; Rose Atoll (Samoan Ids); Tuamotu Ids, Rangiroa, Napuka, and Nganati; Marquesas Ids; Palmyra & Fanning Ids; and Pearl and Hermes Reef, Laysan, and other islands in the Hawaiian group.

Atoll Research in Zoology must include the study of animal species present, in relation to their relatives throughout the entire Indo-Pacific Region (and even in some groups the Atlantic also), before we can fully evaluate each species. It is only by study of the species on and away from atolls, that we may discover facts about each species concerned, to help in any program of development. This is true, whether it be a program of development of greater food supply for the inhabitants, or of improving the yield of such commercial products as Pearl Shell or the Watch & Instrument Oils derived from Porpoises and Dolphins. Ecological studies must be built on an absolutely biologically accurate foundation of species determination.

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VI. (a) - NOTES ON NEEDS FOR ENTOMOLOGICAL RESEARCH ON CORAL ATOLLS

Very little is known regarding the insect faunas of atolls. It is needless to stress our ignorance of the faunas, because it is all too obvious. But there are many more problems than the basic knowledge of just what species occur. We want to know their distributions. How do they fit into the plant-pollenating picture? What percentage of atoll plants are insect-pollenated? What part is played by phytophagous insects and the atoll plants? What about the parasites of birds? Bird diseases spread on atolls by insects? What about insect scavengers and animals? Practically nothing is known about the very interesting and peculiar marine flies which are more widespread in the Pacific than is generally realized. What are the seasonal fluctuations and how are they followed by insect population. Do the insects aestivate or hibernate? What about data on overseas dispersal - a very important point indeed. What conditions are most likely to bring in overseas stragglers? From what directions? What happens to fresh water forms when ponds dry up?

E. C. Zimmerman

VI. (b) BIRDS

Sea Birds:

The opportunity for work with sea birds is, of course, almost limitless. The principal breeding species of atolls are the Man-o'-War Birds, Tropic Birds, boobies and various burrowing or surface-nesting petrels. Not too much is known about the life history of any of these, particularly of the petrels. The ecological interrelations offer a broad field for study, partly in relation to the predatory habits of the Man-o'-War Birds. Even more important is a detailed quantitative study of any or all of these species. We know next to nothing about the seasonal succession of the petrels, for example, in relation to the rainy and dry seasons. We hardly know whether most of the resident species of sea birds breed continuously or have one or two nodes of maximum reproductive activity during the course of a calendar year.

The direction from the islands in which most birds go to feed is also extraordinarily important since this usually bears a direct relation to winds or currents, or both. The petrels and one species of the boobies seem to go much farther from the island than the other species in their regular, foraging, daily journeys. It has been suggested, but never proved, that the petrels are capable of carrying food in the throat and crop in an undigested state for a very long period, up to five or six hours. In the case of birds that feed as far as a hundred and twenty-five miles from a nesting station, this would seem to be a necessary physiological possibility, if the adult birds are going to be able to bring food back to their young, instead of having the process of digestion and assimilation go on within their own bodies during the return flight.

Very much needs to be learned about the migratory species from the northern hemisphere, particularly the shore birds, such as plovers, curlews, sandpipers, godwits, etc. With the exception of a few stations such as Hawaii, at the northern end of the winter range, and New Zealand, at the southern end, we know very little indeed about the movements of these birds and the climatic or other stimuli which mark the beginning of the return flight toward the north.

Still another opportunity is offered by the terns. Nobody knows yet where certain species go after the end of the nesting season. The Sooty Terns, for example, and, in some cases, the white Fairy Terns simply disappear into the immensity of the ocean. At least one Atlantic colony, the Sooty Terns have an interval of about nine months between their breeding periods so that the season of reproduction is constantly changing, or moving forward. Is this true of the same species in the Pacific? Nobody knows.

The eggs of many fish-eating species are perfectly palatable without any of the unpleasant flavor characteristic of the flesh of the same birds. It is possible, moreover, under proper management to take a regular harvest of eggs

from the breeding grounds of certain species, particularly the terns. This was done by the Polynesians over many, many successive generations without any reduction in the maximum numbers of the breeding birds, that is the largest numbers that the nesting areas are capable of supporting. White men, on the other hand, have seriously upset the balance and have even exterminated certain species at certain breeding stations. On the whole, perhaps, the worst of all dangers is offered by man's domestic animals, such as pigs, cats, dogs and, indirectly, of course goats and rats.

Robert Cushman Murphy

Land Birds:

Only very few species of land birds are found on coral atolls and even among these some are not strictly land birds, such as the Reef Heron, the Australian Gray Duck, and certain species of rails. The only real land birds found on some of the islands are fruit pigeons and warblers (Acrocephalus). As far as the fruit pigeons are concerned, we would like to know more about their seasonal movements, particularly from one island to the next and from one group of islands to the next. Are these movements large-scale and are they correlated with the seasonal appearance of certain fruits? What is the status of some of these species in view of the increased shooting on some of the islands? Is there any relation between time occurrence of rails and sea bird colonies?

Ernst Mayr

VI. (c) RATS

While I have not worked on atolls information available indicates that the Polynesian rat (Rattus exulans) is found on some. This rat is introduced by native methods of travel and able to maintain itself in habitats where little fresh water is available. It is not a destructive animal. On atolls where military supplies have been unloaded the destructive Mindanao rat (Rattus mindanensis) and even more destructive Norway rat (Rattusmnorvegicus) may have been introduced. The Norway rat cannot persist under usual conditions found on atolls but the Mindanao rat may. Since each of these three rats has different habitat requirements and different habits before control is attempted the species shou be determined. Control measures for each species on atolls could be worked out without difficulty. Measures to prevent the introduction of the two non-native rats should be investigated.

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VII. CORAL ATOLLS AND MAN

1. The limited potentialities of the environment make the coral atoll of special interest in the study of man in his environmental relationships. The narrow basis for human subsistence entails a certain simplification of the relationships between man and his habitat, and facilitates the analysis of these relationships.

2. In discussing the relationship between man and nature in the atoll environment, one must first clarify what it is that is being related. Previous papers have served to elucidate the distinctive features of the environment. "Man" - the term to which "environment" is being related - can be considered in several ways. We may first consider man shorn of his principal distinguishing characteristic - his culture. The relationship between the atoll environment and man in this sense is primarily in what manner and how well the resources of an atoll supply man's biological needs for survival. When man is considered as a culture-bearer, however, the relationship changes its emphasis and increases in complexity. Here we are concerned with a complex set of relationships between a distinctive environment and a set of traditionally patterned ways of behavior that control man's adaption to the environment and his adaption to his fellows. Traditionally patterned modes of behavior as an aspect of culture.

3. The atoll and man's biological requirements. In this connection, food is the most important factor. The kinds of food available on coral atolls is well enough known, but there is yet to be made an adequate nutrition study of native diet. Furthermore, food is produced through the use of a special set of techniques, by men organized in social groups, and is distributed and consumed according to traditionally sanctioned ways. The study of food production and native diet is most fruitfully examined, therefore, in its cultural ramifications. This brings us to the relationship between the atoll environment and man as a culture bearer.

4. The atoll environment and culture. The first question we may ask is whether the atoll environment is associated with a special culture type. Distinctive aspects of atoll cultures. Examples from Micronesia and Polynesia. The manner in which the atoll environment is related to culture should first be examined with respect to those aspects of culture most closely connected to the utilization of natural resources: technology and material culture; economic organization; social organization. Control of land resources and food production in the Marshalls as an example of the nature of culture-environment relationships. Resumé of present knowledge.

5. Recommendations for atoll research. Kinds of environment-culture relationships needing analysis in the field. Importance of a comparative approach. Type atolls. The factor of change as it affects environment-culture relationships, and the importance of studies through time. High islands and coral atolls. Relevance of atoll studies to problems of native administration. Summary and conclusion.

Alexander Spoehr

VII. (a) AGRICULTURE

Present state of knowledge: Atoll agriculture has two aspects, subsistence and export:

The outlines of the former and existing subsistence agriculture are clear. The native plants and their culture are reasonably well adapted and, supplemented by the sea, have been able to produce an adequate, although somewhat monotonous, diet. These plants, their culture and, in a general way, their desirability and extent of use are known. Knowledge of introduced plant performance is very meager although there are many empirical observations that could be brought together. Some of the obvious factors limiting plant growth are known but there are serious blind spots and there are few actual measures of productivity. A study of the nutritional adequacy of native foods is now under way.

The export agriculture is based entirely on copra and there is scant hope of diversification in the near future. There is little information available on means of increasing production and efficiency under atoll conditions although some such knowledge must have been accumulated by commerical plantations (e.g. Keeling-Cocos).

Suggested future research: Agricultural investigation should not remain the handmaiden of anthropology nor be content with empirical trials of this or that crop or practice. Rather it should aim at anticipating the needs, and providing the policy and leadership for the agricultural development of the area. To do so will require economic studies, crop and soil investigations and educational efforts.

Short term investigations alone are inadequate but can contribute; examples of these are an economic study of copra and the probable future competitive position of the atolls, and a survey of the crops and agricultural practices of the most well developed areas with similarities to the atoll environment. Longer term investigations are necessary for testing new crops, improved varieties and practices, and their utility and acceptance. Such investigations need not be on a large scale but they must be well conceived and carried through for some years.

Shaping of the native agriculture by education and demonstration is a task for extension. The synthesis of economic, biological and anthropological considerations to provide the basic facts and policy for such extension activities, however, is a research task of a high order. In this connection a long term, cooperative "pilot plant" test on a single area should be considered.

Earl L. Stone, Jr.

VIII. LITERATURE ON CORAL ATOLLS

In any serious research project an essential and unavoidable task is to become familiar with what is already known on the subject. The reasons for doing this are not merely to avoid pointless duplication of effort, but to establish a basis for comparison of results, to build a framework of established information into which to fit new findings, to avoid the errors and blind alleys of past work, and to give breadth enough to acquire understanding as well as accumulating information.

In the past it has usually been possible for any individual to depend on his own efforts in becoming acquainted with old literature and keeping abreast of current work. In recent years, however, the sheer volume of publication is such that in a field of any breadth a worker's full time could be spent doing nothing but studying the work of others. Various solutions to this problem are available.

Ignoring the work of others is so limiting that it need not be considered. Narrower and narrower specialization is the commonest path chosen, but the evil effects of this in limitation of understanding and complete loss of over-all significance of work are all too evident. Division of labor along another line is also being more and more resorted to with considerable success. This path lies in the preparation of annotated bibliographies, subject indices, and comprehensive reviews and digests of findings in broad or restricted fields by certain workers whose breadth of background and natural inclinations make them fitted for it. Though, since the days of Agassiz' dictum "Study Nature, not books", there has been a certain stigma attached to bibliographic work and a resentment about money spent for it, there is no question that the realities of the situation are forcing scientists to make more and more use of the work of the professional bibliographer. The success of such reivew journals as Botanical Review, Quarterly Review of Biology, and various industrial scientific journals, as well as the existence of a half-million dollar contract between the U. S. Navy and the Library of Congress to review the results of research sponsored by the Navy alone are ample evidence of the truth of this.

For several reasons the bibliographic work of the atoll project got off to a slow start. However, during the past four months a truly notable amount of work has been accomplished, largely due to the efforts of my capable assistant, Miss Sachet.

On logical, as well as practical grounds, the bibliographic work on atolls divides itself into four major segments. These may be concisely termed marine geology, marine ecology, land ecology, and anthropology. Our efforts, up to the present, have been concentrated on the third of these major divisions. It is felt that the monumental bibliography brought together by W. M. Davis in his volume on The Coral Reef Problem, in 1928, together with the unexcelled

bibliographic services of modern American geology, largely eliminate the need for any intensive work on marine geological bibliography. Marine ecology and anthropology are such extensive and important fields, in themselves, and with such enormous literatures, that the resources of the present bibliographic phase of the project would be dissipated without significant results if an effort were made to include them. Furthermore, it is felt that in fields of such great practical and popular interest it should not be very hard to secure funds for comprehensive bibliographic studies if the workers in these fields feel the necessity for them.

The field of land ecology has been construed as broadly as is necessary to cover the entire literature on atolls that is left after the other three segments have been removed. It includes the geography, the land geology, the climatology, the water supply, the soils, the vegetation, the fauna and flora, the economic plants, the agriculture, and the uses made of the natural resources by the people.

The bibliographic work on this divides itself naturally into two parts, the location and evaluation of the literature that exists, and the abstracting and organization of the part of this that seems significant and useful.

The first part results in an annotated bibliography of all the literature known on atolls, with annotations describing and evaluating the content of the papers sufficiently to enable the user to determine which papers he should consult for his own purposes. This includes a subject cross index to make it easily and efficiently used. This bibliography is nearly complete, though there will be many papers that will turn up that we have overlooked, especially in the field of systematic zoology. It is hoped that we have the most important ones. The total number of papers has turned out to be about twice as many as we estimated at the beginning. We hope to be able to find a publisher for this work to make it available generally. Meanwhile, a preliminary manuscript is being typed which will be deposited in the Pacific Science Board offices in Washington and Honolulu, and the files are being kept open for additions and for consultation, by the Pacific Vegetation Project.

For the second part we have set up a series of filing folders, classified in every way that we can think will be significant. Into these we are putting information abstracted from the papers that seem to be of enough interest to be worth abstracting. Copies or cross references are inserted for each item in every folder where it is pertinent. A copy of the abstracts is sent to the Honolulu office so that a duplicate file may be kept there. A visit was made to Yale University, where all material fitting into this scheme in the Cross Cultural Survey files was copied for insertion into this system. In addition, unpublished field notes are included wherever available. Though much information has already been inserted, an enormous amount remains to be done on this part of the project.

It is contemplated that, as time goes on, digests may be made and issued of the information accumulated on specific fields based on this abstracted data. It may be possible, after the greater part of the abstracting is done, to prepare

such digests to order to meet the needs of individual workers on the project. This would save much preliminary work for those engaged in the various aspects of the project, and might well save them from overlooking important information, and might direct their researches into important fields that could be overlooked otherwise.

It is felt that with another year of work, this bibliography and abstract file will be an extremely effective aid to atoll research. It also may serve as a model for similar work in the other major divisions of the atoll field.

F. R. Fosberg